**INTRODUCTION**

The Mountain Ringlet *Erebia epiphron* is found locally at high altitude in Europe, with colonies in Scotland and Cumbria in the north and in the mountains of southern and central Europe to the south (the Pyrenees, Alps and Bulgarian mountains). The altitude range in southern Europe is wide, from 500–3,000m (Chinery, 1998), but it is narrower in the UK being 500–700m in Cumbria and 350–900m in Scotland (Asher *et al.*, 2001).

Mountain Ringlet is considered to be under-recorded (Asher *et al.*, 2001), both in the UK and Europe as a whole, owing to its remote montane habitat. McGowan (1997) studied the distribution of Mountain Ringlet in Scotland by obtaining historical records from various sources: the National Museums of Scotland, the Invertebrate Site Register, the Scottish Diurnal Lepidoptera Project, and Butterfly Conservation. McGowan obtained further records in 1994 using a questionnaire targeted at 250 entomologists, naturalists, mountaineers and conservation agencies, of which 91 were returned. For both historical and questionnaire records only those with at least 1km grid reference resolution were used, and these enabled the aspect and the altitude of the observations to be determined. Data on vegetation type (grassy, heath, woodland or other) were available from many of the returned questionnaires. The underlying geology at a site influences the nutrient status...
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of the soil and the vegetation communities present in the area. Therefore, information on the underlying geology at all these Mountain Ringlet sites, which were distributed in 43 10km squares, was obtained from 1: 625 000 British Geological Survey maps.

Using all this information, McGowan (1997) was able to identify that there were large areas with apparently suitable habitat for Mountain Ringlet in Scotland but no historical records. Forty-three apparently suitable sites were visited in 1995 by McGowan and Mountain Ringlet found in 19 of them, relating to eight 10km squares. This confirmed that Mountain Ringlet is under-recorded in Scotland.

**The 2008/2009 Survey**

There are concerns that climate warming will affect the species, and two recent papers have argued that Mountain Ringlet colonies at low altitude in Cumbria and Scotland are becoming extinct owing to recent warming (Hill et al., 2002; Franco et al., 2006).

Climate warming is a concern for other invertebrates which live at high altitude too; consequently in 2008 and 2009 Scottish Natural Heritage funded fieldwork to collect baseline data on the distribution and altitude range of montane invertebrates in Scotland, including Mountain Ringlet. The results of the Mountain Ringlet survey are presented in this and a second paper (Masterman, in press).

A Global Positioning System (GPS) device was used to record the position of each Mountain Ringlet sighted during the survey in 2008 and 2009. This enabled each observation to be allocated to the correct 1km square and altitude. A total of 1,741 observations were recorded by the author and a further 533 by volunteers. A web page and a downloadable survey form were created to encourage volunteers to search for Mountain Ringlet and to record vegetation data in the 1km squares in which the butterfly occurred.

**Altitude Range**

The mean altitude of the Mountain Ringlet observations was 684m in 2008 and 675m in 2009 with 95% occurring between 460–902m. The altitude ranges (difference between highest and lowest altitudes) were 568m and 576m in 2008 and 2009 respectively. In both years there was a trend in the altitudes of Mountain Ringlet observations to increase later in the flight period, which may be the result of individuals emerging later at higher altitudes and not dispersing large distances. The possibility that this is due to movement uphill by individuals that had emerged earlier in the season at lower altitude has been
considered. However, earlier research into distances flown by Mountain Ringlet at Ben Lawers, Perthshire (Bayfield et al., 1994) suggest this is not the case. Using mark and recapture techniques the distances travelled by 54 Mountain Ringlet were measured: recapture times varied from 10 minutes to 11 days with an average recapture time of 32 and 57 hours for males and females respectively. The rate of movement was just 2.96 m/h for males and 1.5 m/h for females; it was concluded that movement by Mountain Ringlet at Ben Lawers was random with little evidence of dispersal and there was also little evidence of deliberate or wind-assisted dispersal.

### 10KM DISTRIBUTION

The distribution of Mountain Ringlet at the 10km resolution in Scotland is shown in Figure 1, including two new 10km squares gained during the survey work in 2009. Mountain Ringlet has a curiously limited distribution, being confined to the central highlands from Ben Lomond in the south to Creag Meagaidh in the north, and from Glen Creran in the west to Schiehallion in the east with a couple of outlier colonies in the Cairngorm mountains (Glen Doll and Glen Feshie). There are large areas of Scotland with suitable altitude of 350–900m but no Mountain Ringlet records.

### 1KM DISTRIBUTION

The distribution of Mountain Ringlet at 1km resolution using records from Butterfly Conservation up to 2007 is shown in Figure 2. These records have been grouped into 13 different populations relating to different mountain groups in Scotland; they correspond
to 243 1km squares. An interesting feature of Figure 2 is that there is a hole in the middle of the distribution, yet the centre of a distribution might be where the highest density of a population would be expected. In this case it is the absence of high mountains on Rannoch Moor and the presence of Loch Leven and Loch Rannoch which account for the lack of Mountain Ringlet records in the centre of its distribution.

Survey work in 2008 and 2009 searched for Mountain Ringlet in 222 1km squares in areas with historical records: Mountain Ringlet was found in 145 (65%) of these squares. The species had not previously been recorded from 73 of these 145 1km squares (Figure 3) but they were mostly adjacent to squares with historical records. These new squares related to 11 of the 13 populations described in this paper.

McGowan (1997) presented a graph showing a large increase in Mountain Ringlet records during the 1980s and the first half of the 1990s. Up to 1982, the total number of Mountain Ringlet records and the number of 1km and 10km squares to which they related were 56, 42 and 21 respectively. For 1983 to 1995 the comparative figures were 98, 72 and 34. The 73 new 1km squares in 2008 and 2009 increases the total number of 1km squares with records of Mountain Ringlet from 243 in 2007 to 316, representing a 30% increase. The two new 10km squares gained in 2008 and 2009 mean Mountain Ringlet is now known from 53 10km squares. These statistics suggest that Mountain Ringlet is still under-recorded in Scotland owing to its remote montane habitat.
HABITAT

The foodplant of Mountain Ringlet is Mat-grass *Nardus stricta*, which is very common on the mountains of Scotland as prolonged sheep-grazing favours swards rich in Mat-grass (Fenton, 1937). Previous research at Creag Meagaidh and Ben Lawers National Nature Reserves (Baines, 1993; Boyd-Wallis, 1994 and Bayfield *et al.*, 1994) found that Mountain Ringlet is more abundant in areas with a combination of abundant Mat-grass and abundant nectar plants, particularly Heath Bedstraw *Galium saxatile*, Meadow Buttercup *Ranunculus acris* and Tormentil *Potentilla erecta*.

McGowan (1997) obtained data on the underlying geology of 10km squares in which Mountain Ringlet has been recorded and found that sites with Mountain Ringlet tended to be moderately base-rich or base-rich, rather than acidic. This is consistent with the large number of 1km squares in the southern half of its distribution (Figure 2), which relate to the Breadalbane mountains with base-rich soils as a result of the underlying geology of Dalradian schists.

The findings of this previous research were examined further in 2009 using the data recorded by the author and the volunteers who recorded vegetation data. The hypothesis that the distribution of Mountain Ringlet is dictated by the distribution of herb-rich *Nardus* grassland was tested by comparing the abundance of Mat-grass and five nectar plants in 153 1km squares within the range of Mountain Ringlet with their abundance in 20 1km squares outside the known range in the Cairngorms. The 153 1km squares were a random selection on mountains with previous Mountain Ringlet records, whereas the 20 Cairngorm 1km squares were selected on the basis of suitable altitude and aspect (south-facing with altitudes between 400 and 800m) and accessibility. The five nectar plants were Heath Bedstraw, Meadow Buttercup, Tormentil, Wild Thyme *Thymus polytrichus* and Alpine Lady’s Mantle *Alchemilla alpina*, all of which have been noted as good indicators of Mountain Ringlet habitat (Paul Kirkland, pers. comm.).

Mountain Ringlet *Erebia epiphron* habitat in Coire Odhar at Ben Lawers NNR within the Breadelbane mountains. Mat-grass *Nardus stricta* is extensive here and the species is common along the butterfly transect (Photo: A. Masterman).

Herb-rich Mat-grass swards at Cam Chreag with Wild Thyme *Thymus polytrichus*, Heath Bedstraw *Galium saxatile* and Tormentil *Potentilla erecta* (Photo: A. Masterman).
A scoring system was used to measure the abundance of Mat-grass and nectar plants, the area with suitable aspect and altitude, and the incidence of sheep-grazing in each 1km square. Within each 1km square a minimum walk of 500m was achieved, including at least five gullies (where both Mat-grass and nectar plants tended to be most abundant) and areas between gullies. Eight variables were quantified in each 1km square, as follows:

- Mat-grass. A score of zero applied where the extent of Mat-grass in the 1km square was estimated to be less than 10ha (there are 100ha in a 1km square), a score of one where 10–30ha was estimated, and a score of two where more than 30ha was estimated.
- Aspect/altitude. As Mountain Ringlet is known to be associated with south-facing aspects and an altitude range of 350–900m (Asher et al., 2001) an estimate of the area of each square with south-facing aspect in the 400–800m range was made. A score of zero applied where this was less than 10ha, a score of one where it was 10–30 ha, and a score of two where more than 30ha.
- Nectar plants. For each of the five nectar plants the abundance scores were zero where absent, one where present in gullies, two where abundant in gullies, and three where abundant within and outside gullies.
- Sheep grazing. A score of zero applied where sheep grazing or signs of sheep grazing were not observed, and a score of one where present.

The sum of these eight scores (a maximum of 20) is termed the habitat score.

Habitat scores for the 20 1km squares surveyed in the Cairngorms on mountains with no Mountain Ringlet records were compared with the habitat scores from mountains within the known range of Mountain Ringlet. Three t-tests were performed. The first compared the full dataset of 153 1km squares with the 20 Cairngorm squares and the result was highly significant: \( t = 9.10, \text{df} \ 171, P < 0.001 \). Mountain Ringlet was found in 99 of the 153 1km squares within the range of Mountain Ringlet where habitat scores were obtained. The second t-test compared the habitat scores of these 99 1km squares with...
the 20 Cairngorm squares and the result was also highly significant: \( t = 8.79, \text{df} 117, P < 0.001 \). These two t-tests showed that habitat scores for the 20 Cairngorm squares were significantly lower than the habitat scores of the 1km squares within the known range of Mountain Ringlet. This supports the hypothesis that the limited distribution of Mountain Ringlet can be explained by the distribution of herb-rich *Nardus* grassland.

The third t-test compared the habitat scores of the 99 1km squares within the range of Mountain Ringlet in which the butterfly was found with the 54 1km squares where Mountain Ringlet was not found. This test was also significant (\( t = 4.66, \text{df} = 151, P < 0.001 \)) and also supports the link between herb-rich *Nardus* grassland and Mountain Ringlet.

The hypothesis that higher numbers of Mountain Ringlet are found in 1km squares with higher habitat scores (which reflect a higher abundance of Mat-grass and the nectar plants) was also tested. Figure 4 shows the relationship at the 5% level between the Mountain Ringlet numbers in the 99 1km squares and the habitat scores, which confirms the association between herb-rich *Nardus* grassland and Mountain Ringlet found by previous research (Baines, 1993; Bayfield *et al.*, 1994; Boyd-Wallis, 1994). A habitat score of ten or more appears to relate to higher numbers of Mountain Ringlet.

Further analysis investigated the relationship between habitat score and the eight scores used to calculate it. All eight constituent scores were positively correlated at the 0.1% level with the habitat score, indicating that they all contributed to the habitat score and that they should all be retained in any future surveys using this methodology.

Two National Vegetation Communities (NVCs) have been identified as suitable habitat for Mountain Ringlet (Bayfield *et al.*, 1995; Averis *et al.*, 2004): U5 *Nardus stricta-Galium saxatile* grassland and CG11 *Festuca ovina-Agrostis capillaries-Alchemilla alpina* grass-heath, but the author does not have the appropriate experience to classify NVCs in the field. Mat-grass is the dominant constituent of U5 and both Heath Bedstraw and Tormentil are characteristic species (Rodwell, 1991). Of the 153 1km squares within the range of Mountain Ringlet 73% and 83% had the highest abundance score of three for Heath Bedstraw and Tormentil respectively. Heath Bedstraw and Tormentil are also characteristic species of CG11, together with Alpine Lady’s Mantle, Wild Thyme and Mat-grass. Alpine Lady’s mantle and Wild Thyme had the highest abundance score of three in 27% and 25% of the 153 1km squares respectively.

These statistics on the abundance of the nectar plants, together with the data on the abundance of Mat-grass in the 153 1km squares, support the hypothesis that both U5 and CG11 NVCs are associated with Mountain Ringlet habitat. U5 is found mainly at altitudes of 300–700m but may sometimes occur up to c.800m, whereas CG11 is found at higher altitudes of 800–900m (Averis *et al.*, 1991). Therefore, at sites with a range of altitudes, such as Ben Lawers NNR, Mountain Ringlet may be associated with U5 on the lower slopes and CG11 higher up. Further work comparing Mountain Ringlet observations with NVC data from specific mountains is required.

In both 2008 and 2009, only a small proportion of the Mountain Ringlet seen by the author and volunteers were observed to be nectaring (actually probing with their proboscis rather than just sitting on a flower). Only 15 Mountain Ringlet were observed nectaring in July 2008 by the author owing to poor weather. Warmer conditions in late June and early July 2009 resulted in a total of 43 observations of Mountain Ringlet nectaring on 11 different mountains. In decreasing order, the percentages of the 43 Mountain Ringlet choosing the following nectar plants were: Tormentil 37%; Meadow Buttercup 28%; Wild Thyme 26%; Dandelion *Taraxacum officinale* 7%; and Heath Bedstraw 2%.
These observations support those of Boyd-Wallis (1994) at Creag Meagaidh NNR who also found Tormentil and Meadow Buttercup to be the preferred choice of nectar plant by Mountain Ringlet. However, at Ben Lawers NNR Bayfield et al. (1995) observed 320 Mountain Ringlet nectaring and found 67% on Heath Bedstraw, 17% on Tormentil, 7% on Thymus spp., 5% on Alchemilla spp. and 2% on other species. Interestingly, only one Mountain Ringlet was observed nectaring on Heath Bedstraw in both 2008 and 2009, and in each case the location was Ben Lawers NNR.

**CONCLUSION**

Mountain Ringlet is termed a habitat specialist by Butterfly Conservation (Asher et al., 2001) as its habitat is localized and restricted to discrete patches of semi-natural habitat. Previous research at Creag Meagaidh and Ben Lawers NNRs (Baines, 1993; Boyd-Wallis, 1994 and Bayfield et al., 1994) suggested that the semi-natural habitat which Mountain Ringlet requires is herb-rich Nardus grassland.

The survey work in 2009 confirmed this earlier research, showing that higher numbers of Mountain Ringlet occur in 1km squares with a higher abundance of Mat-grass and nectar plants, and that 1km squares outside the range of Mountain Ringlet in the Cairngorms have significantly less Mat-grass and nectar plants. These results provide a plausible explanation for the limited distribution of Mountain Ringlet in Scotland.

Currently there are no records of Mountain Ringlet north of the Great Glen and a lack of herb-rich Nardus grassland may be the explanation for this; it is also possible that the climate is too cold, or the species is present but is simply under-recorded. Further survey work from mountains north of the Great Glen is required to complete the understanding of this aspect of Mountain Ringlet ecology. Indeed further survey work within the known range of Mountain Ringlet would also be beneficial as this paper suggests that Mountain Ringlet is still under-recorded in Scotland.

**ACKNOWLEDGEMENTS**

Special thanks are due to volunteers Lawrie and Bridget de Whalley who surveyed 26 different 1km squares for Mountain Ringlet near Tyndrum in 2009. The efforts of other volunteers in 2008 and 2009 are also gratefully acknowledged. The historical data used in this report represents the observations of many people whose efforts in recording this butterfly in remote and high altitude locations are also gratefully acknowledged.

The research detailed in this paper is one aspect of a wider research project funded by Scottish Natural Heritage, involving the National Museums of Scotland, National Trust for Scotland, the John Muir Trust and Butterfly Conservation to increase the knowledge and understanding of Scotland’s montane invertebrate fauna.

**REFERENCES**


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**ERRATA**

*Atropos* 40: 39. Figure 1 was incorrectly reproduced, omitting some of the information for more recent years. It is reproduced in full here.

![Figure 1](image-url)

*Figure 1.* The numbers of adult male Gypsy Moth *Lymantria dispar* caught in pheromone traps in north-east London, 1995–2009. The number of traps placed out each year is given in brackets below the columns.